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1220228

DRAWINGS ATTACHED

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## (54) ELECTRIC MACHINES

(71) We, TOKYO SHIBAURA ELECTRIC COMPANY LIMITED, Japanese corporate body, of 72 Horikara-cho, Kawasaki-shi, Japan, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to dynamoelectric machines such as induction machines, synchronous machines, direct current machines, and alternating current commutator machines, and to induction voltage regulators, including wedges arranged to improve cooling effect for coil conductors contained in stator and/or rotor cores.

According to the present invention an electric machine comprises a stator, a rotor spaced from the stator by an air gap, the rotor and/or the stator including a magnetic core having slots and at least one radial ventilating duct, coils contained in the slots, and a plurality of wedges driven into each slot to secure the coils therein, the wedges of each slot being disposed with gaps therebetween so that each wedge has no direct contact with an adjacent wedge whereby cooling air is permitted to flow in direct contact with the surfaces of said coils.

The invention can be more fully understood from the following detailed description when taken in connection with the accompanying drawings in which:

Figure 1 is a longitudinal sectional view of dynamoelectric machine embodying this invention;

Figure 3 is an enlarged side view of part of the stator shown in Figure 1;

Figure 3 shows a section of the stator taken along a line III—III in Figure 2;

Figure 4 is a development view of a modification of the stator part;

Figure 5 shows a diagram to illustrate an arrangement of two layered coils;

Figure 6 is a developmental view of a portion of the stator of a dynamoelectric machine employing two layered coils;

Figure 7 is a developmental view of a portion of the stator of a dynamoelectric machine employing one layered coils; and

Figures 8 and 9 are partial developmental views of stators employing other arrangements of wedges.

Referring now to the accompanying drawings, Figure 1 shows a longitudinal sectional view of an induction motor as an example of the dynamoelectric machine. Inside a frame 1 is secured a stator core 3 comprising a plurality of laminated thin iron sheets with radial air ventilation ducts 2 at predetermined spacings. Stator coils 4 are disposed in slots of the stator core 3 to complete a stator 5.

A rotor 6 spaced from the stator by an annular air gap comprises a rotor core 11 comprised by a plurality of laminated thin iron sheets with spaced air ducts 10, a shaft 9 journalled by bearings 8 supported by end brackets 7 secured to the opposite ends of the frame 1, and rotor conductors 12 disposed in the slots of the rotor core 11.

Cooling of stator 5 and rotor 6 is provided by circulating air through the air ducts 10 in the rotor core 11 and through the air ducts 2 in the stator core 3 in the direction shown by arrows by air circulating fans 14 secured on both ends of the rotor rim 13.

The invention is characterised by the arrangment of wedges which securely hold, in the present embodiment, the stator coils 4 in stator slots.

More particularly, as schematically shown in Figures 2 and 3, stator coils 4 provided with ground insulations are contained in the slots 15 of the stator core 3. After insertion of stator coils wedges 16 having a configuration shown in Figure 3 are driven into the openings of the slots 15. The wedges 16 are located with gaps therebetween instead of being driven in end-to-end abutting relationship throughout the axial length of the slots, as has been the usual practice.

Figure 4 shows a modified arrangement of wedges for a stator core 3 comprising a plurality of sections S, T, U, V, W, Y and Z separated by air ducts 2. In the slot 15a, wedges 16a are driven into core sections S, U, W and Z, while in the next slot 15b wedges 16b are driven into core sections T, V and Y. In the third slot 15c wedges 16c are driven into core sections S, U, W and Z, while in the slot 15d wedges 16d are driven into core sections T, V and Y.

With this arrangement, each gap G between adjacent wedges driven into slots 15a to 15d to clamp the radially inner surfaces of respective coils contained therein is communicated with two air ducts, and wedges in adjacent slots are staggered in the axial direction.

Air ducts 2 are defined by interposing spacers between laminations of sections S, T, U, V, W, Y. and Z when they are stacked in frame 1. To communicate gaps G of adjacent slots the air ducts 2 are not required to extend between the inner and outer peripheries of the core but may be defined by cutting away teeth of the core to an appropriate depth from the air gap.

In this manner, by driving wedges into core slots with gaps G therebetween, the surfaces of coils 4 are brought into direct contact with the cooling air in the gaps G, thus greatly improving the cooling effect of the air. Being constructed in the ordinary manner the opened end of each slot 15 is formed to have a dove-tail shaped cross-section to receive the wedge so that the sum h of the lengths AB and BC is substantially larger than the length AC i.e., the radial thickness of the wedge. Assuming now that the circumferential width s of the core tooth equals 10 mm, that the thickness of the wedge 16 equals 3.5 mm and that h=5 mm, then the surface area $S_a$ of the core contributing to cooling could be expressed by an equation $S_a=(s+2h)/s=(10+2\times 5)/10=2$ at portions where there is no wedge, thus doubling the effective area. If it is assumed that the total length of portions of the slot that do not contain wedges amounts to 2/3 of the axial length of the slot the surface area of the core contributing to cooling would be increased by a factor of 1.7.

Further, by the arrangement shown in Figure 4, the surfaces of the coils between wedges 16a, 16b, 16c and 16d which are driven into respective slots 15a, 15b, 15c, and 15d, of the stator core 3 are exposed to the air gaps G, each communicating with two air ducts 2. Therefore, cooling air sent by fans 14, shown in Figure 1, will enter into slots 15b, and 15d, and thence flow to gaps G in each slot through air ducts 2 as indicated by arrows in Figure 4. Thus, the cooling air effectively cools not only the coils in the slots but also portions of the slots which do not contain wedges whereby the cooling effect of the air is greatly improved.

When the invention was applied to a 450 KW, 3,600 rpm squirrel-cage type induction motor the quantity of air passing through air ducts was increased about three times and the temperature rise of the coil was decreased from 76°C to 68°C.

In the embodiment shown in Figure 4, as each coil 4 is secured in position by spaced apart short wedges 16, when the ground insulation of the coil is relatively soft and the wedges will thrust into the ground insulation and damage it.

Figure 5 is a diagram to show one example of the arrangement of various phase conductors wherein two layered coils consisting of upper and lower coils are disposed in each slot 15 of the stator core 3. This diagram shows the arrangement for a three phase two pole machine having 18 slots wherein slot numbers per pole per phase q=3, and pitch equals to 1—9 or $\frac{9-1}{9}=88.9\%$. Circles, squares and triangles represent phase coils of U, V, and W phases respectively. As can be readily understood from the drawings, in slots 3, 6, 9, 12, 15 and 18 are received upper and lower coils belonging to different phases whereas in other slots upper and lower coils belong to the same phase. In slots containing upper and lower coils belonging to the same phase, as current flows through these coils always in the same direction, these upper and lower coils attract each other to urge them against the bottom of the slot. Thus there is no force tending to force out wedges. On the contrary, in slots containing coils of different phases, during the period in which current flows in the opposite direction through upper and lower coils, a repulsion force will be created between these coils tending to force out the upper coil together with wedges. If the wedges are not strong enough to withstand this force they would be dislodged. Further, clearance between the wedge and the coil will result in the vibration of the upper coil thus causing such fault as dislodging of the wedges and damage to insulation.

In the arrangement shown in Figure 6, the spacings between adjacent wedges 16 are made small for slots containing upper and lower coils 4 belonging to different phases

but large for slots containing coils of the same phase. Considering slot number 9 containing upper and lower coils belonging to different phases wedges 16b are driven in each of core sections S, T, U, V, W, Y and Z whereas wedges 16a, 16c and 16d are driven in slots 8, 10 and 11 respectively of alternate core sections, each containing coils belonging to the same phase, said wedges being spaced by appropriate gaps which serve to expose portions of the surface of coils to increase their cooling effect. The gaps between wedges driven in slots containing coils belonging to different phases are reduced to prevent dislodging of coils due to repulsive force.

Figure 7 shows an embodiment of this invention wherein slots of a stator core 3 contain one layered coils 4. In a dynamoelectric machine with one layered coils, as current always flows in the same direction through coils contained in all slots, coils are normally urged against the bottom of the slots. Thus there is no force created by current tending to force out coils. For this reason, wedges 16 driven into slots are not required to have a strong strength and the spacings between them may be increased to expose larger area of the coils to cooling gas thus increasing the cooling effect.

Figures 8 and 9 illustrate two similar modifications utilising wedges 16 each comprising a wide section 16Z and a narrow section 16W. Narrow section 16W of each wedge is protruded out of the core 3 where it is clamped to the coil 4 by a cord 18 to prevent the wedge from dislodging.

While in the above embodiments the invention has been shown as applied to the stator of an induction motor it will be obvious to one skilled in the art that the invention can also be applied to armatures of dynamoelectric machines including wound rotors of induction motors, stators or rotors of synchronous machines, alternating current commutator machines and direct current machines, as well as to rotors and/or stators of induction voltage regulators having substantially the same construction as induction motors.

WHAT WE CLAIM IS:—

1. An electric machine comprising a stator, a rotor spaced from the stator by an air gap, the rotor and/or the stator including a magnetic core having slots and at least one radial ventilating duct, coils contained in the slots, and a plurality of wedges driven into each slot to secure the coils therein, the wedges of each slot being disposed with gaps therebetween so that each wedge has no direct contact with an adjacent wedge whereby cooling air is permitted to flow in direct contact with surfaces of said coils.

2. An electric machine according to Claim 1, wherein the wedges of adjacent slots are staggered from each other in the axial direction.

3. An electric machine according to Claim 1 or Claim 2, wherein the coils are two layered consisting of upper and lower coils contained in the slots of said core, and the wedges driven in the slots containing coils belonging to the same phase are spaced relatively widely apart whereas wedges driven in slots containing coils belonging to different phases are spaced relatively closely together.

4. An electric machine according to Claim 1, wherein the coils contained in the slots of said core are one layered coils.

5. An electric machine according to Claim 1, wherein the wedges include a portion of reduced dimension which portion protrudes outside the core and is secured to the coil.

6. An electric machine substantially as hereinbefore described with reference to Figures 1 to 4 of the accompanying drawings.

7. An electric machine substantially as hereinbefore described with reference to Figures 1 to 3, but as modified by Figure 6 of the accompanying drawings.

8. An electric machine substantially as hereinbefore described with reference to Figures 1 to 3, but as modified by Figure 7 of the accompanying drawings.

9. An electric machine substantially as hereinbefore described with reference to Figures 1 to 3, but as modified by Figure 8 of the accompanying drawings.

10. An electric machine substantially as hereinbefore described with reference to Figures 1 to 3, but as modified by Figure 9 of the accompanying drawings.

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1220228 COMPLETE SPECIFICATION

3 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

FIG. 1

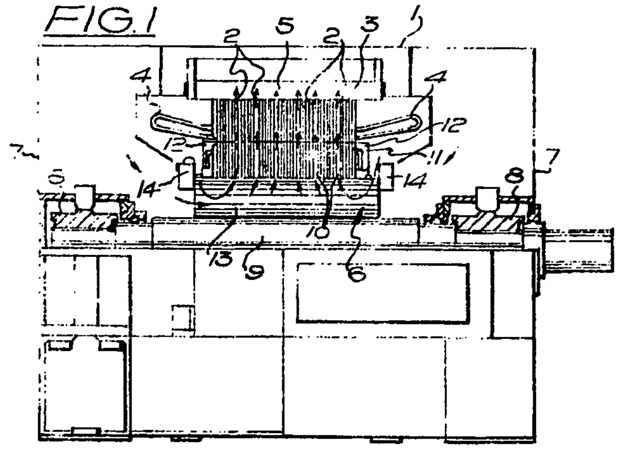



FIG. 2

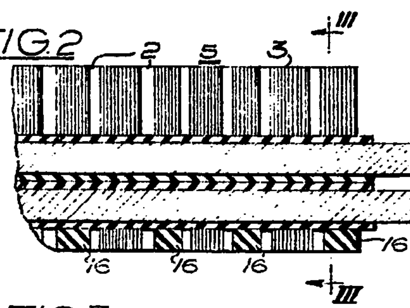
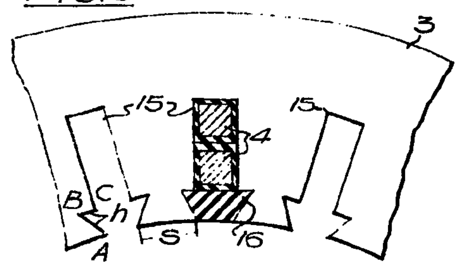



FIG. 3



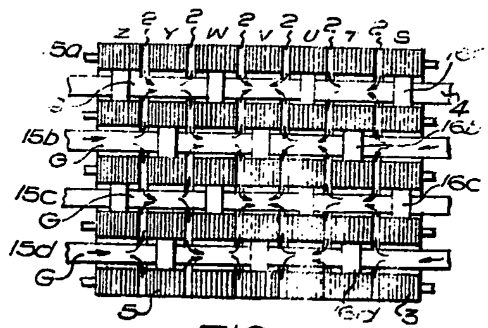



FIG.4

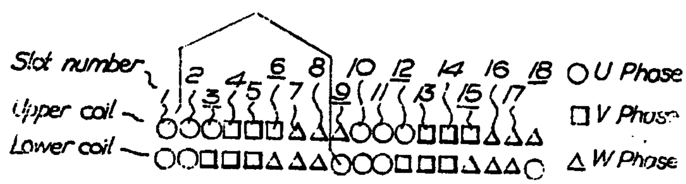



FIG.5

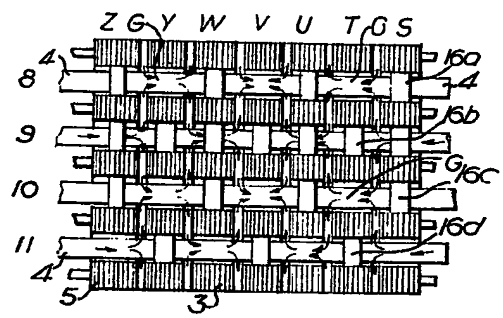



FIG.6

1220228 COMPLETE SPECIFICATION

3 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

**Sheet 3**

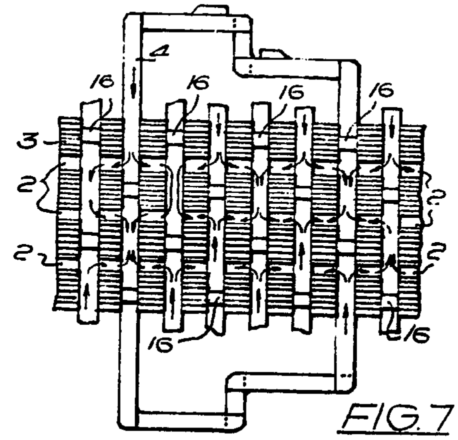



FIG.7

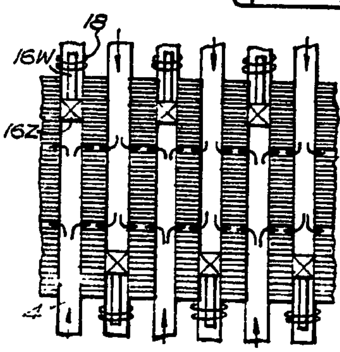



FIG.8

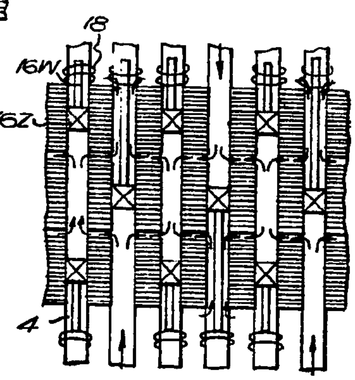



FIG.9